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ABSTRACT

The Zimbabwe Secondary School Science Project (ZIM-SCI) developed student study guides, corresponding teaching guides, and science kits for a low-cost science course which could be taught during the first 2 years of secondary school without the aid of qualified teachers and conventional laboratories. This ZIM-SCI study guide presents activities and experiments for a three-part unit in which students investigate: (1) the chemical compounds found in the earth's crust and atmosphere; (2) the characteristics of metals and non-metals; and (3) the extraction of iron from red iron oxide and the purification of copper. Information to help students understand the scientific principles behind the activities and experiments is provided. (JN)

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ZIM-SCI

ZIMBABWE SECONDARY SCHOOL SCIENCE PROJECT

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STUDY GUIDE UNIT F2

The Chemicals of the Earth

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UNIVERSITY OF ZIMBABWE
AND MINISTRY OF EDUCATION AND CULTURE

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ZIM-SCI

ZIMBABWE SECONDARY SCHOOL SCIENCE PROJECT

GENERAL SCIENCE

STUDENTS: Please read this carefully. It will help you.

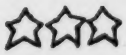
How you will study

This Study Guide comes to you with a kit of apparatus. Both things are part of a study programme leading you to an understanding of aspects of science. In this course you will be carrying out experiments. The Study Guide will help you to understand the scientific principles behind the experiments.

Your work should be done as you are instructed, either by the teacher or the Study Guide.

To help you to see quickly what you must do, the Study Guide uses these symbols:

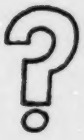
for "Read and revise your notes and Study Guide"



for "Take note of an important point that you should learn"

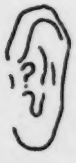
for "Summary. This is to help you to go over what you have learned"

for "Experiment"
When you see this sign, read the instructions carefully from beginning to end before you start to do the experiment.



for "How much do you know?"
This is for you, to help you to test whether you are remembering what is important.

for "Written work"
This is when you must answer questions in writing.



for "Listen to the teacher and do exactly what the teacher tells you to do"

for "Activity"
This symbol will appear whenever you are asked to do something without your apparatus.

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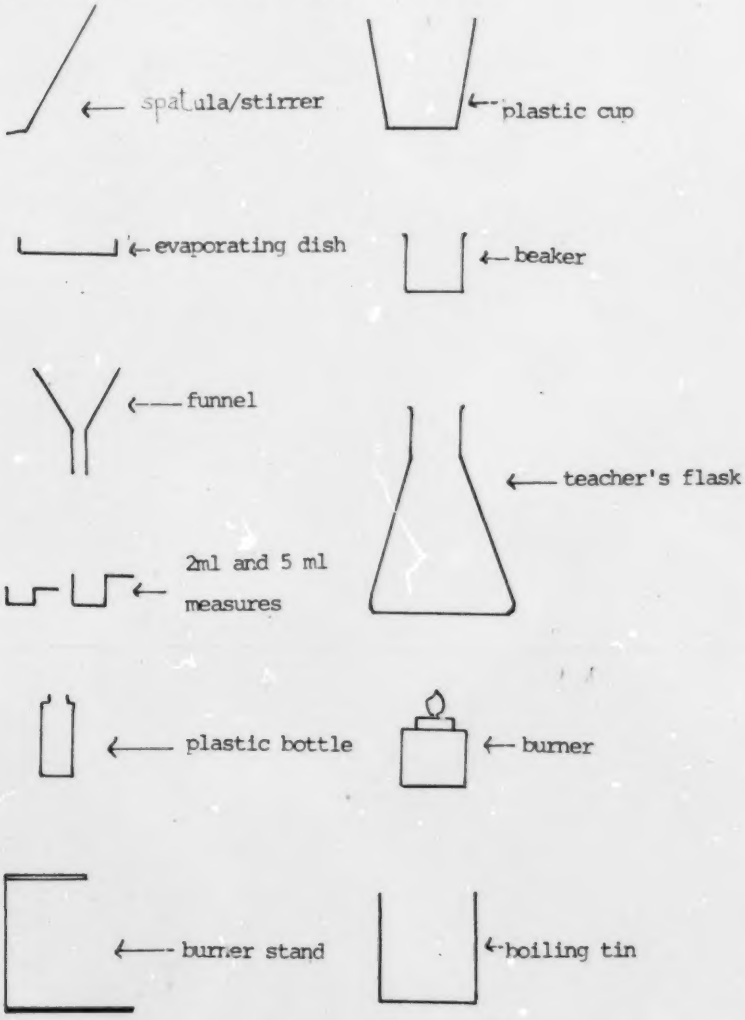
Making scientific diagrams

Previous units have had pictures of apparatus to show you how to do experiments. These pictures take a long time to draw. Now that you are writing out all your experiments you need to learn to do neat drawings quickly. Scientists use special diagrams to show the apparatus they use. Your teacher will explain them to you.

Here are some diagrams of the apparatus you are likely to use in your experiments.



AIMS OF THIS UNIT

When you have completed this study unit you will be able to:

1. Explain by means of pie charts the rough composition of the earth.

2. Describe the composition of air and the effect of burning various elements.

3. Describe chemical tests for some gases.

4. Describe some characteristics of metals.

5. Explain that most common metals are reactive and thus found as compounds.

6. Describe how iron may be extracted from ores by displacement.

7. Describe how copper can be purified by a process using electrical energy.

UNIT F2 : THE CHEMICALS OF THE EARTH

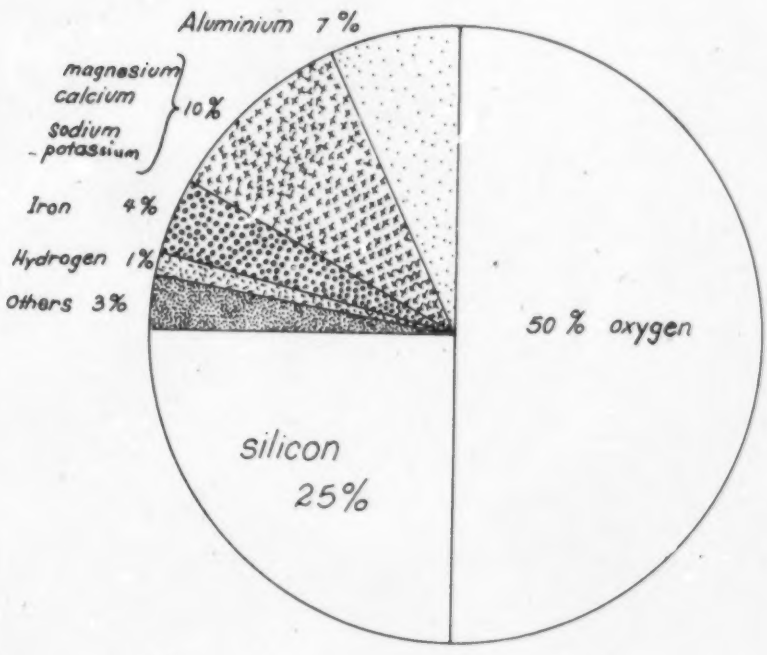
Part I. THE EARTH AND THE ATMOSPHERE

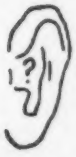
In Unit F1, you learnt how the earth was formed. You also learnt about some of the rocks which are found in the earth's crust. In this unit, you are going to look at some of the chemical compounds which are found in the crust and in the atmosphere above the earth.

The whole earth is made of many different chemical compounds. As you know, these compounds are made from elements. Before you study the composition of the earth, tell your teacher all the elements that you can remember. The teacher will write them on the board.

Did you make a long list? Many of the elements that you suggested will not be found naturally on earth as elements by themselves. They will be found in combination with others, making compounds. If an element is very REACTIVE (an element which easily takes part in a chemical reaction is called reactive) it will never be found alone but will always combine with others. The rocks and the soil which you studied in the last unit are all compounds which have formed from elements which react quite easily. For example, dolerite is a compound made of aluminium, iron, magnesium, oxygen and an element called SILICON.

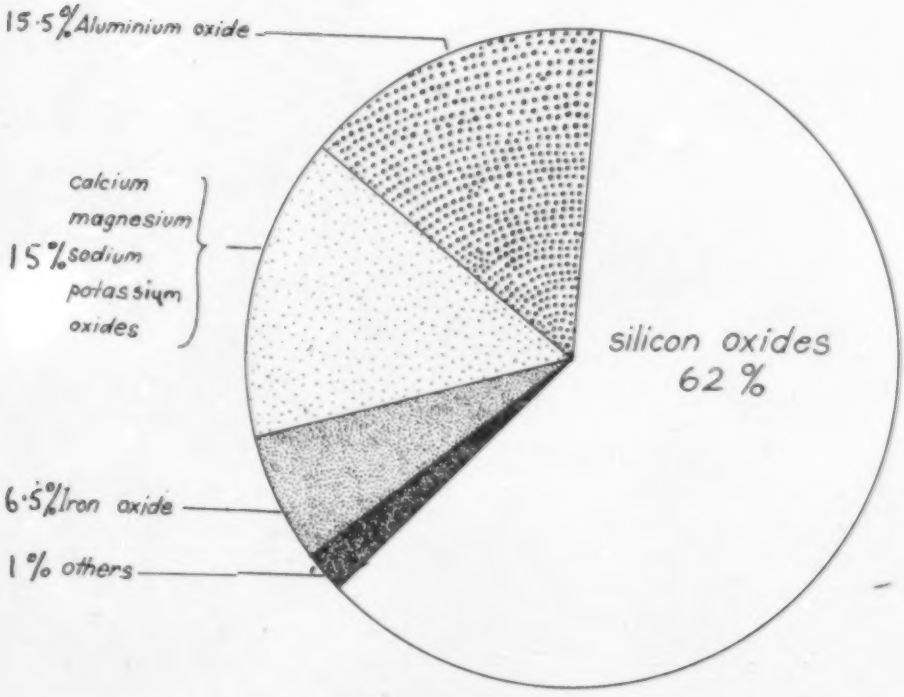
If an element is found on earth in large amounts scientists say that it is COMMON. If there is only a small quantity, the element is RARE. Here is a Pie Chart giving the approximate percentage of the most common elements in the earth's crust and atmosphere taken together.





You will see that there are large amounts of oxygen and silicon. Some of the oxygen is in the air as oxygen gas, some is in the water and some is in the earth's crust in combination with other elements to make compounds. Can you remember any compounds that you have studied which contain oxygen? Your teacher will be able to tell you some more!

All the elements in the pie chart occur naturally in compounds. We can make another pie chart to show the most common compounds. It looks like this:-



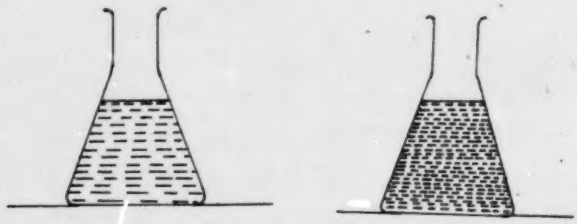
So far we have not separated the compounds of the crust and the atmosphere.

As you know, the air is made up of gases. It is in fact a mixture of several gases. Can you remember the properties of a mixture? Revise that section of Unit C1 with your teacher. From now on, we shall refer to the atmosphere as "air."

There are many chemical reactions that take place in air. You will be trying some in a moment. Before you start, however,

your teacher has a magic trick to show you!
See whether you can work out what is happening!

EXPERIMENT 1. A magic trick



When you are sure that you understand how the magic trick works, answer Exercise 1.

The next experiment will take a few days to give a good result. Be patient !

EXPERIMENT 2. To observe the reactions between
(a) steel wool and air
(b) magnesium and air

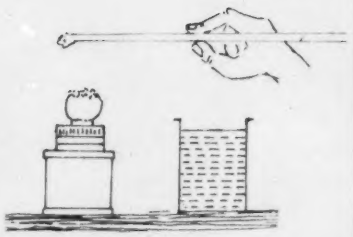
You will need:

piece of magnesium ribbon (2 cm long)
small piece of steel wool (about 3 cm x 1 cm)
2 straws
burner
2 small pieces of filter paper (each 2 cm x 1 cm)
methylene blue indicator
water
plastic cup filled with water
scissors
ruler
scalpel

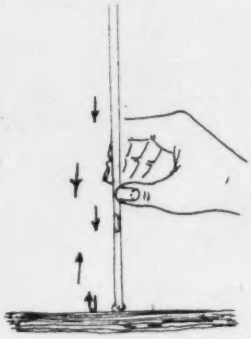
Follow the flow chart for this experiment.

7

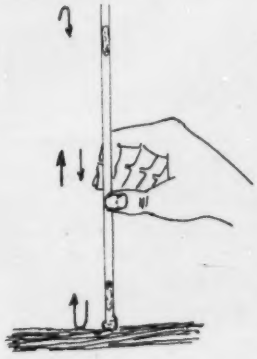
1. First you must close one end of each straw. Light your burner. Hold a straw in one hand. Wet the thumb and first finger of the other hand with water. Now hold the straw with the end about 5 cm above burner flame, turn it round while you count to three and quickly take it out and pinch the end closed with your wet finger and thumb.
   Check that it is closed properly by trying to blow through it with the closed end in your cup of water.
   Repeat with the second straw.



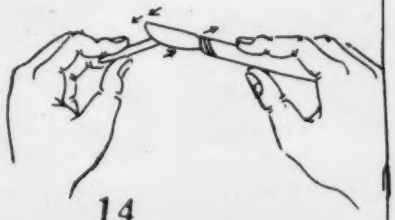
2. Roll up a piece of filter paper into a tube small enough to slide down the straw. Tap the straw to get the filter paper to the closed end or push it down with a piece of grass. Repeat for the second straw.



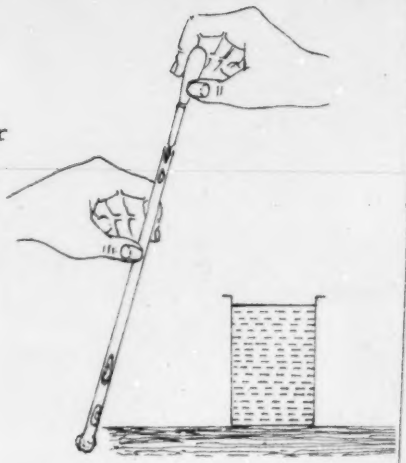
3. Twist and roll the steel wool and put it into the first straw. Tap it to get it to the closed end or use the piece of grass again.



4. Clean the magnesium by scraping it with a scalpel or razor blade until the surface is shiny.
   Put it into the second straw.

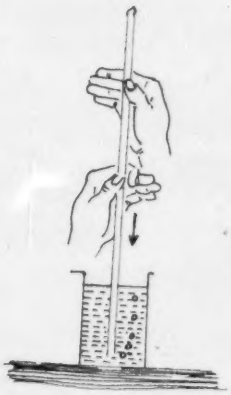


5. Drop 5 drops methylene blue indicator into each straw so that the filter paper is all wet. The blue colour should show clearly.

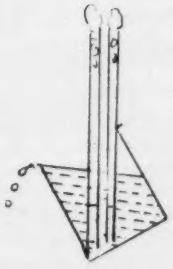


6. Put the straws into the plastic cup with the open end down.

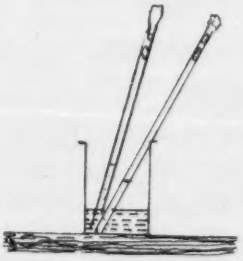
7. Squeeze some of the air out of each straw, by pinching the straw and moving your fingers down it while keeping the open end under water. The water will come in to take the place of the air you have squeezed out.



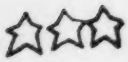
8. <u>Carefully</u> pour out <u>most</u> of the water from the cup so that the level of water in the straws is above the level of water in the cup.



9. Measure the length of the air space in each straw. Leave undisturbed for several days. Then answer Exercise 2.

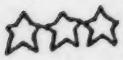


When the steel wool was left in contact with the damp air, you observed rust on the surface of the steel. You also observed that about one fifth of the air was used up in the rusting. The filter paper changed from blue to white, which was the change of colour expected when the oxygen was taken away.
Therefore you can deduce that:

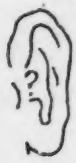


1. Rusting used up oxygen
2. The oxygen filled up one fifth of the air space.

The magnesium was not so easy to see. However, after several days you observed a black colour on the surface of the magnesium. It lost its shine. This is called TARNISHING. The process was very slow, so you could not observe all the oxygen being used up. You might have noticed a change in filter paper colour from blue to white. Therefore you could deduce that



3. Tarnishing used up oxygen.



Your teacher will now show you an element called CALCIUM. He will show you a tarnished piece and then scratch it for you to see that it is shiny underneath like the magnesium ribbon. What happens if you burn calcium in the air?

EXPERIMENT 3. To burn a piece of calcium.

You will need

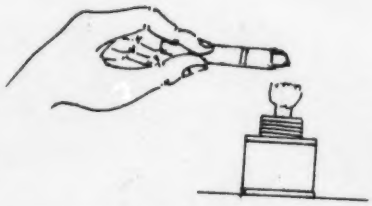
small piece of calcium (about 2 cm long)
scalpel
peg
burner

1. Hold the calcium with the peg, NOT with your fingers. Scratch the surface with a scalpel until it is shiny over quite a large area (see diagram 1).

2. Now hold it with the peg in the flame of the burner (diagram 2). What do you notice?

Diagram 1

Diagram 2

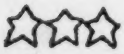


Answer Exercise 3.

You can see that the result of burning calcium is the same as that of tarnishing. A white substance forms on the outside of the calcium and the reaction uses up oxygen.

When a chemical substance burns, rusts or tarnishes in oxygen (or in air containing oxygen) a product is formed that has the word 'oxide' in its name. For example:

magnesium burns (or tarnishes) to form MAGNESIUM OXIDE
iron burns (or rusts) to form IRON OXIDE
calcium burns (or tarnishes) to form CALCIUM OXIDE

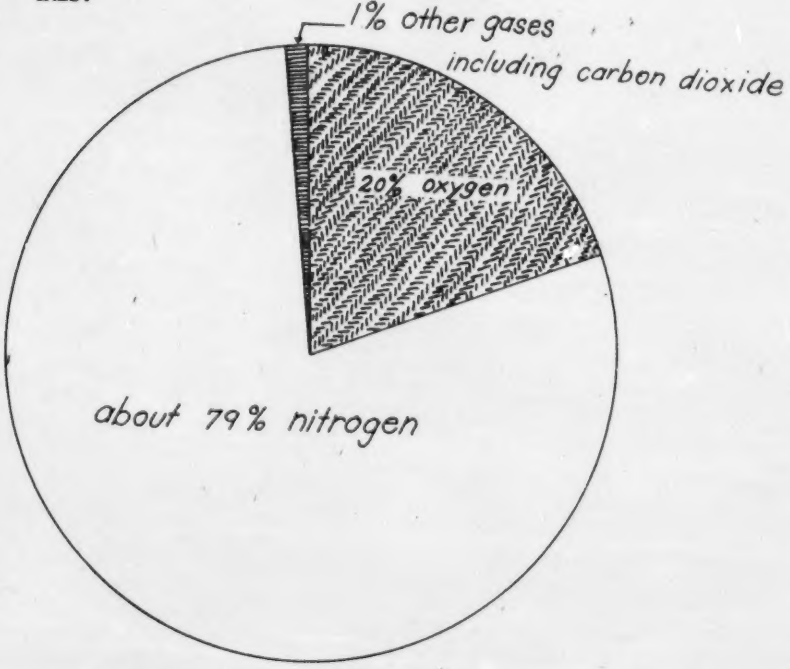


Don't forget the test for oxygen gas: IT GIVES A BLUE COLOUR TO METHYLENE BLUE

A substance which changes colour when mixed with a particular chemical can be a very useful test for that chemical. Such a substance is called an INDICATOR. Methylene blue indicates when oxygen is present.

Oxygen is just one of the gases that are mixed together to form air. Your experiments so far have shown that oxygen can be removed from air very easily - by rusting, for example. This supports our idea that air is a MIXTURE. The rest of this mixture is mainly the gas called NITROGEN. Nitrogen is not very reactive and you cannot do any experiments with it at the moment.

A complete pie chart showing the composition of the air looks like this:



You can see that there are small amounts of several other gases in air - one of which is CARBON DIOXIDE

Carbon dioxide is an oxide formed when another element called CARBON burns. Carbon is found in all fuels. A common quite pure kind of carbon is CHARCOAL. Note DI-OXIDE means <u>two</u> atoms of oxygen for every one atom of carbon in a molecule of carbon dioxide.

☆☆☆ You can test for the presence of carbon dioxide by using an indicator called BICARBONATE INDICATOR. This is reddish blue when carbon dioxide is <u>not</u> present. What colour is it when carbon dioxide is present? You can see the colour change now. You are going to make some carbon dioxide by burning carbon in air.

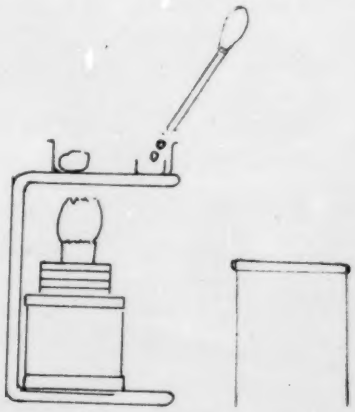
EXPERIMENT 4: To make carbon dioxide and observe bicarbonate indicator.

You will need :

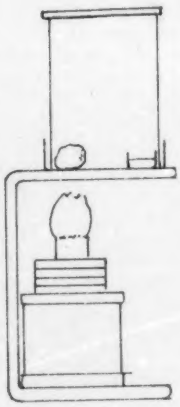
burner with stand
evaporating dish
boiling tin
indicator dish (your teacher will show you what this is).
pieces of charcoal
bicarbonate indicator

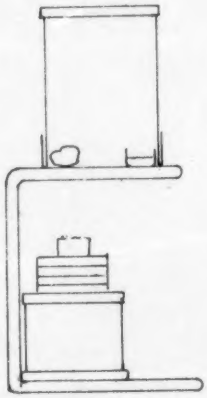
1. Set up the apparatus as shown in the diagram. Put 5 drops of indicator in the indicator dish. You should be able to see the reddish blue colour clearly.

2. Heat up the charcoal until it starts to glow red.

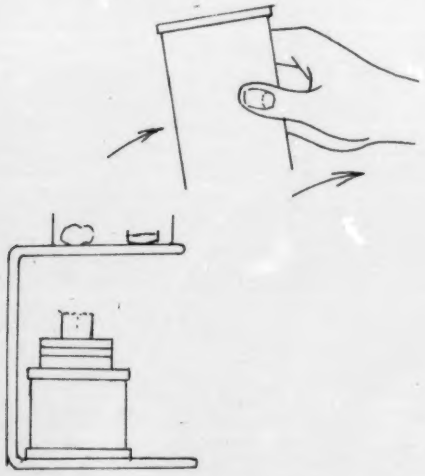


3. Place the boiling tin upside down over the whole evaporating dish to trap the gas carbon dioxide and continue to heat for half a minute before blowing out the burner.





Leave the boiling tin over the top for FIVE MINUTES before you lift it up to see what has happened. What colour is the indicator now?



Answer Exercise 4.

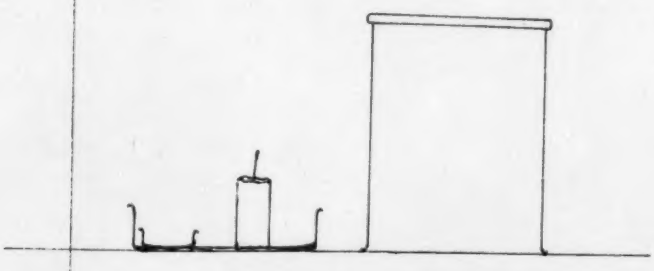
You will now do a second experiment using the bicarbonate indicator to investigate a burning candle.

EXPERIMENT 5: Investigating a burning candle

You will need:

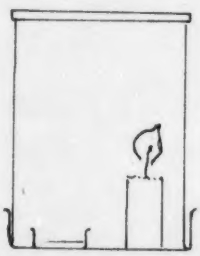
- candle
- boiling tin
- matches
- evaporating dish
- indicator dish or lid from small plastic bottle
- bicarbonate indicator
- water

Set up the apparatus as shown in the diagram:

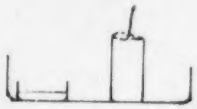


Put 5 drops bicarbonate indicator in the indicator dish. It should be reddish blue in colour. Now light the candle.

SLOWLY AND CAREFULLY lower the boiling tin right over the lid and candle.



Allow the whole thing to stand for about 5 minutes. Lift the boiling tin and look at the indicator. What colour is it now?



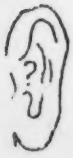
Answer Exercise 5.

You now know <u>two</u> tests for gases.

To summarise them:

OXYGEN turns methylene blue from colourless to blue

CARBON DIOXIDE turns bicarbonate indicator from reddish blue to yellow.



It is also useful to have indicators which are not just used for one chemical test. Your teacher will now give you a piece of UNIVERSAL INDICATOR PAPER. This special paper changes to different colours in many different chemicals and is extremely useful to help classify compounds into groups. Listen to your teacher now as he tells you about universal indicator paper. You can then try it out for yourself.

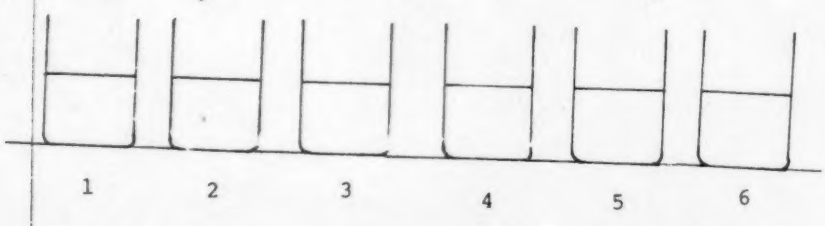
EXPERIMENT 6: To observe colour changes of universal indicator paper.

You will need:

Universal Indicator Paper

Your teacher will place the following liquids on his desk:

1. hydrochloric acid
2. water
3. sodium carbonate solution
4. copper sulphate solution
5. ammonia
6. sodium chloride solution



Tear off small pieces of universal indicator paper and dip the ends into the solutions. Use a new piece for each solution and do not get your fingers wet. Compare the colour with the colour key and report the pH of each solution.

(Exercise 6 Part 1)

You will have noticed that the middle point of the pH scale is at 7. If a substance has a pH of less than 7, we say it is an ACID. If it is more than 7, we say it is a BASE. If it is exactly 7, we say it is NEUTRAL. That is, it is neither acid nor base.

Can you divide up the substances you tested into acids and bases? Answer Exercise 6, Part 2.

What happens when an acid meets a base? You can find out now!

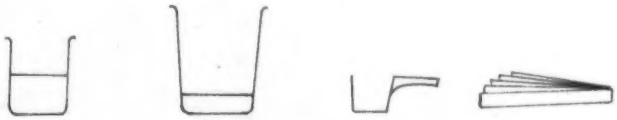
EXPERIMENT 7: To add an acid to a base

You will need:

plastic beaker exactly half full (25 ml) of sodium carbonate solution

plastic cup containing about 25 ml hydrochloric acid

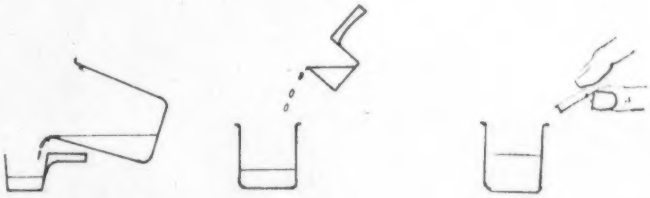
5 ml measure.



BE CAREFUL: hydrochloric acid burns the skin. If you get any on your skin or your clothes, wash it off with plenty of water and TELL YOUR TEACHER.

Copy down the questions for Exercise 7 before you begin and answer them as you go along.

1. Add 5 ml hydrochloric acid to the sodium carbonate in the plastic beaker.
   Observe what happens. Test the pH with Universal Indicator Paper and record your results.



2. Add another 5 ml acid to the base. Test the pH again and continue to report the values. Go on in this way until the acid is all used up. Complete Exercise 7 when you have finished the experiment.

Your teacher will discuss this experiment and show you a model which helps to explain what happens.

An acid always reacts with a base. However, the products do <u>not</u> always include a gas! This reaction was special because the sodium carbonate released a gas. What do you think this gas is? Your teacher will discuss this.

Think back to your experiments with limestone and marble in Unit F1. Can you now make a guess about the kind of chemical compound these rocks must be? Discuss this with your teacher.

Now that you have seen what can be done with universal indicator paper, you can use it to determine the pH of some solutions that you will make for yourself. These solutions will be formed by burning some elements and dissolving the product of the burning.

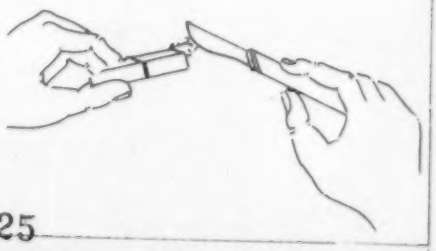
<u>EXPERIMENT 8</u> Part 1. <u>Determination of the pH of calcium oxide solution</u>

You will need :

- calcium
- burner
- peg
- mounted needle or scalpel for scraping
- plastic beaker half full of water
- universal indicator paper.

Hold the calcium in the flame, using a peg until white calcium oxide forms all over the outside of the calcium.

Scrape off quite a lot of the oxide onto a piece of paper. Now transfer the oxide from the paper into the water in the plastic beaker. Stir well and test the pH with indicator paper.



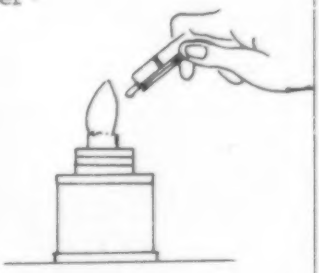
Record your result in Exercise 8 part 1.

Clean the plastic beaker well for the next experiment.

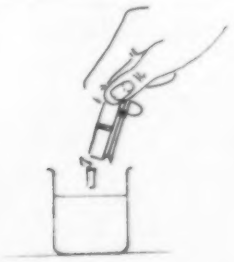
EXPERIMENT 8 Part II. Determination of the pH of magnesium oxide solution

You will need :

piece of universal indicator paper
2 cm piece of magnesium ribbon
peg
burner
plastic beaker half full of water



Hold the piece of magnesium ribbon in the burner flame using your peg.



As soon as it catches alight, drop it into the water in the beaker and stir well.

Test the pH and record the result in Exercise 8, part 2.

Clean the beaker very well again.

EXPERIMENT 8 Part III: Determination of pH of sulphur dioxide solution

You will need:

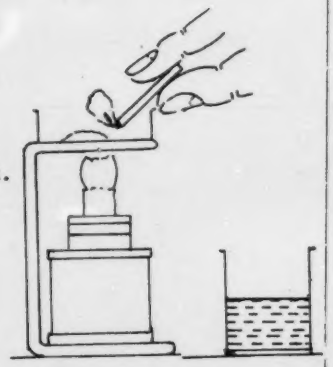
½ spatula sulphur in your evaporating dish

burner and stand

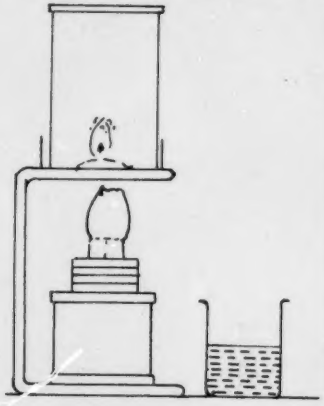
boiling tin

plastic beaker half full of water

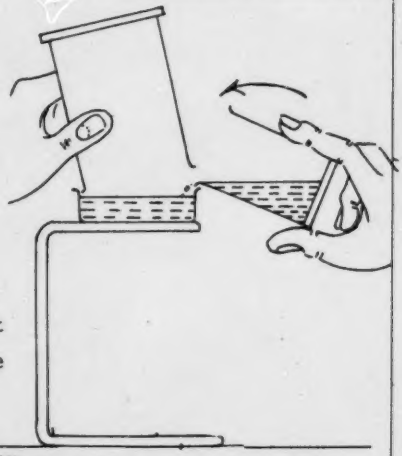
Read all the instructions before you begin.
Heat the sulphur until it catches alight with a blue flame.
(You can help with a match if it takes too long.)



As SOON as it flames, QUICKLY place the boiling tin over the top and continue heating for a further quarter of a minute.
Then remove the burner.



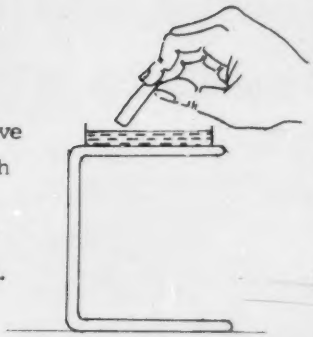
Lift one edge of the boiling tin, throw the water from the beaker all over the hot evaporating dish and sulphur and replace the boiling tin as quickly as possible.



It is most important to be quick and lift the tin as little as possible because the sulphur dioxide which forms is a gas and will escape easily.

Wait five minutes for the gas to dissolve then remove the tin and test the pH with universal indicator paper.

Record the pH in Exercise 8, Part 3.



You know that carbon dioxide is also a gas. Can you design the experiment to find the pH of a carbon dioxide solution? Record the pH you get in Exercise 8 part IV

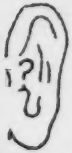
You have seen that carbon dioxide disssolves in water easily, and that the resulting solution is ACIDIC. Rain water can dissolve carbon dioxide from the air and become acidic too. Can you remember what happened in Unit F1 when you dropped some limestone onto an acid? That's right - a chemical reaction took place and the limestone dissolved. Rocks can be weathered in this way, by the chemical action of the acidic rainwater. Don't forget this important way of weathering! To finish off Part I of this unit, you can now investigate the pH of jiffy juice crystals and of toothpaste.

EXPERIMENT 9: pH of Jiffy Juice and Toothpaste

Your teacher will give you:

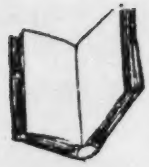
- a few drops of jiffy juice solution
- a few drops toothpaste solution

Use your universal indicator paper to find out the pH of these solutions.

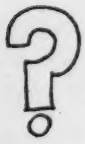


Can you now explain the observation you made in Unit A1 that your sense of taste deceived you? What happened when the jiffy juice met the toothpaste in your mouth? Discuss this with your teacher.

Your teacher will show you items from the first aid kit: the substance which is marked "for acid in eyes' and that marked 'for alkali in eyes'. He will test their pH for you. Can you explain how they work?



To summarise this part of the unit, read and revise what you have learned so far.
Then answer "How much do you know?"



HOW MUCH DO YOU KNOW?

1. The most common elements in the earth's crust are ..... and .....
2. The most common compound in the earth's crust is .....
3. The indicator which tells us when oxygen is present is ...
4. In the presence of oxygen it turns from ..... to .....
5. Air is a mixture made up mainly of ..... and .....
6. The indicator which tells us when carbon dioxide is present is .....
7. In the presence of carbon dioxide it turns from ..... to .....
8. When carbon burns it forms ..... When this is dissolved in water it turns Universal Indicator paper ..... Which means it is .....
9. When sulphur burns it forms .....
10. When magnesium burns it forms .....
11. When calcium burns it forms .....
12. Acids have a pH between ..... and .....
13. Bases have a pH between ..... and .....
14. Explain the use of Universal Indicator Paper.

PART 2: METALS AND NON-METALS

What is a metal? This is a word that you have often used, but I wonder whether you have ever stopped to think why a metal is different from any other kind of chemical? I expect you have some ideas on the subject, as you can probably imagine a 'metal ' in your mind. What are you imagining?

You can now get your ideas on metals sorted out so that you can judge whether any given substance is a metal or a non-metal. To do this, you will have to examine some substances and try to sort them into two groups. You will look at their physical properties and their chemical properties.

Your teacher will give you small amounts of eleven different chemicals, most of which are elements. Check with the list below:

EXPERIMENT 10: Sorting out metals and non-metals

You will need

- carbon rod
- cotton wool
- 3 cm magnesium ribbon
- 2 cm square aluminium foil
- ½ spatula sulphur (in evaporating dish)
- 2 cm calcium
- 1 iron nail
- 2 cm copper wire
- 2 cm square lead foil
- used matchstick
- piece of candle wax.

Let us try to separate them using chemical properties first. You burned some of these substances in your experiments in Part I of this unit, and you discovered that the product of the burning was an oxide. Some of the oxides were acidic and some

were basic. Can you remember which was which?
Put the substances you burned into two groups, one for acidic on the left of the desk and one for basic on the right side of the desk. You should have six substances left which you have not placed in a group and which you have not tested by burning. Cotton wool and wood are compounds with a lot of carbon in them. Use this fact to put them into one of your groups

You now have four substances left. Have a look at their appearance. Compare them with the groups you have made. Which group fits them best? Try to guess! When you have decided, you must put them into the group so that all the substances have been sorted out into the two groups and you have none left.

Now look carefully at your two groups. Is there a group you would like to call 'metals' ? Can you guess which group makes basic oxides and which groups makes acidic oxides?

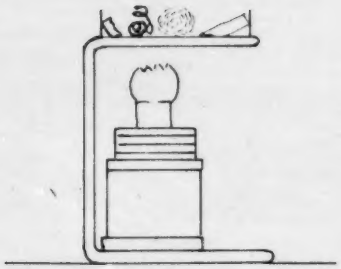
Are there other differences between the two groups? You have already noticed that they LOOK very different - you used their appearance to help you to classify them! What other prope can you investigate?

Before you go on to find out more about metals and non-metals you must draw a table so that you can compare your results. Copy Table 1 into your books and fill in the first column, with 'basic' or 'acidic'. You can then continue with your experiments.

EXPERIMENT 11. Heating metals and non-metals

For this experiment you will need two metals and two non-metals. You will need:

copper wire coiled around
aluminium foil folded in four
carbon rod
cotton wool
evaporating dish
burner and stand



Place all the substances so that they are resting in the dish, and heat over the burner for about fifteen seconds. Then remove the burner.

Feel each substance carefully with the tips of your fingers. Some will be much hotter than others! Record your results in your table.

The dish itself is made of iron Can you record that result too?

EXPERIMENT 12: Scraping and bending metals and non-metals

For this experiment you will need:

Scalpel or mounted needle

Metals : aluminium foil
copper wire
lead foil

Non-metals: matchstick
cotton wool
candle wax

1. Scrape the surface of each of the six substances to see whether it is shiny or not.
2. Bend each of the substances to see whether it bends without breaking and stays bent.
3. Record all your results in columns three and four of the table.

Then answer Exercise 9.

Now that you have found out the most important differences between metals and non-metals, you can look at the metal group and try to discover more about them. You can give all the non-metals back to your teacher.

To find out more about metals, some more *chemical properties* must be investigated. You already know that metals form basic oxides when they react with oxygen. The next reaction that you will test is between metals and water. Before you begin, copy down Table 2.

EXPERIMENT 13 : To find out whether all metals react with water.

You will need :

samples of magnesium, calcium, iron, copper, and lead
water
evaporating dish
scalpel
burner and stand

1. Carry out the following test on each of the five metals. Scrape the surface very well. Half fill the evaporating dish with water. Drop the piece of metal into the water and observe the surface of the metal very carefully. Record your results in the table.

   If the metal reacted with the water, you can deduce that it is a VERY REACTIVE METAL.
   If it is less reactive, it might react with water on heating. Try the next part of the experiment with all the metals which did not react in the cold water.

2. Heat the water in the evaporating dish to boiling and test each of the metals which did not react with cold water again. Record your results in the table.

If the metal reacted with hot water but not with cold, it is QUITE REACTIVE.
If it did not react with water at all, you should now test it with acid.

EXPERIMENT 14: Reacting metals with acid

You will need

metals which did not react with water
hydrochloric acid
evaporating dish
burner and stand

Carry out this experiment on the metals remaining, exactly as you did with the water. Those which do not react with cold acid may be tested with hot acid.

REMEMBER TO BE CAREFUL - ACID BURNS THE SKIN!

When you have completed this experiment, you will be left with just a few metals which are VERY UNREACTIVE.

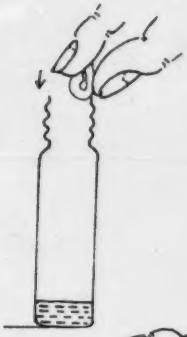
Draw up a table of activity now for the metals you have studied (Exercise 10)

You have seen that when you put some metals in hydrochloric acid there is a reaction. Can you remember what showed you there was a reaction? Good. Bubbles of gas were coming out! You are now going to have a closer look at this gas.

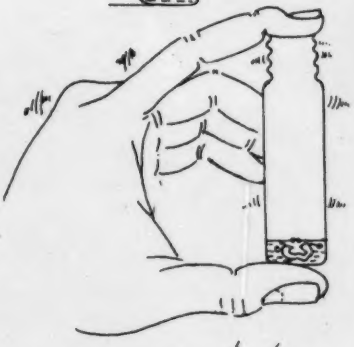
EXPERIMENT 15: <u>Investigating the gas produced when a reactive metal reacts with an acid.</u>

You will need:

2 ml hydrochloric acid
2 cm piece of magnesium
1 plastic bottle
matches

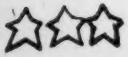


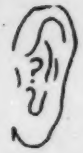
Pour <u>all</u> the acid into the plastic bottle. Make a ring out of the magnesium. Drop the ring of magnesium into the acid in the bottle.



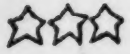
As the reaction is seen to be taking place, close the mouth of the bottle with one of your fingers. This way you will have collected a lot of this gas above the liquid in the bottle.

After about 2 minutes light a match stick. Bring the flame near the closed mouth of the bottle. Now remove your finger so that the gas comes into contact with the flame. What do you hear? Good. You hear a sound. It is usually described as a 'pop'sound. A 'pop' sound indicates that a gas called HYDROGEN is present. Hydrogen is a colourless gas which burns. If you observe carefully you might see a pale blue flame burning at the mouth of the bottle after the 'pop' and feel the warmth of the burning reaction.





You used magnesium and hydrochloric acid to produce the hydrogen gas. Which of the chemicals you used do you think is a source of hydrogen i.e. contains hydrogen? Discuss this with your teacher.



ALL acids contain hydrogen which can be displaced by metals. You will learn more about acids in later units.

The last kind of chemical reaction that you are going to do in this part of the unit is the reaction between a metal and sulphur. In Unit C1, you reacted iron and sulphur to make iron sulphide. Copper and lead can be reacted with sulphur in the same way, to make copper sulphide and lead sulphide.

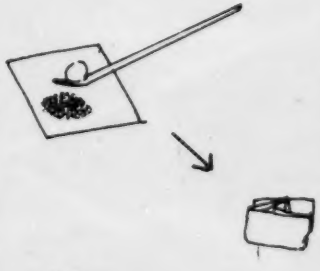
EXPERIMENT 16: Reacting metals with sulphur

You will need:

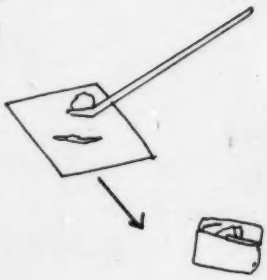
three squares of aluminium foil (4 cm x 4 cm)
3 spatulas sulphur
1 spatula iron filings
1 square of lead foil (1 cm x 1 cm)
½ spatula copper turnings or a small piece of copper wire
evaporating dish
burner and stand

Follow the flow chart for this experiment.

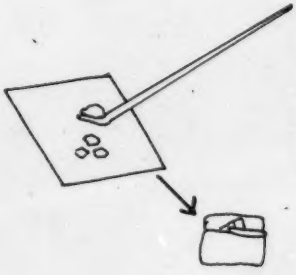
1. Onto the first square of aluminium foil put 1 spatula sulphur and 1 spatula iron filings. Mix up very well. Fold foil into a flat parcel.



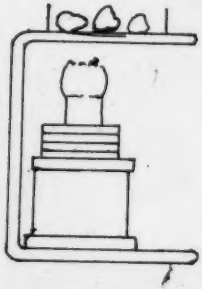
2. Onto the second square of foil put 1 spatula sulphur and ½ spatula copper turnings or the copper wire. Mix up well and fold into a parcel.



3. Tear up the lead foil into small pieces. Mix these with the last spatula of sulphur and parcel up in foil.

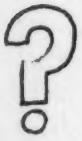


4. Put all three parcels next to each other in the evaporating dish. Heat over the burner for about three minutes. Allow to cool before opening the parcels to look at the sulphides.



Answer Exercise 11.

Before going on to the last part of this unit, read and revise this section. Then answer "How much do you know?"



HOW MUCH DO YOU KNOW?

1. Describe all the properties of a METAL
2. Write down an activity series for the metals you have studied, starting with the most reactive and finishing with the least reactive.
3. Describe how you produced hydrogen gas.
4. Describe a test for hydrogen.

PART 3: THE EXTRACTION OF METALS

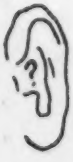
From all your experiments in this unit, you have found that some metals are more reactive than others. The most reactive were calcium and magnesium. They were so reactive that they reacted with the air to form a thin skin of oxide on the surface of the metal. This skin prevented the metal from reacting further, so you had to scrape it off before you did any more experiments. When you scraped it, you saw the shiny metal underneath.

Aluminium presents a problem in the laboratory because it is in fact a very reactive metal. You were not able to observe this at all. The reason why aluminium seemed to be completely unreactive is that a thin skin of aluminium oxide on the surface prevented any kind of reaction. Scraping the surface is no good because as soon as you scrape, the oxide forms again, so you can never get it all off! You cannot observe the oxide film because it is very thin.

You can now fit it into your activity series. Its proper place is between magnesium and iron.

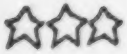
Now that you have discovered something about the reactivity of metals, you will be able to guess something about how they are found in the earth. If a metal is very reactive, it will not be found on earth as an element. It might react with air, or water, or with other elements, to form compounds. Commonly occurring compounds are oxides and sulphides, in which a metal has joined up with oxygen or sulphur.

If a metal is not very reactive, it might be found on earth as an element all by itself.



Here is a long list of metals, placed in order of their activity. Look at the list and try to guess whether the metals will ever be found as elements, or only in the form of compounds. Discuss the list with your teacher.

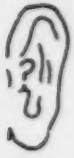
The activity series



potassium - most active
sodium
calcium
magnesium
aluminium
zinc
iron
lead
copper
silver
gold - least active

If a metal is very reactive, it is very difficult to get the metal out of its compounds. Sometimes we want to use a metal by itself, so the oxide or sulphide compound will be no good. We have to get the metal away from the oxygen or sulphur with which it is combined. This may need a large amount of energy.

In Unit C2, you combined iron and iodine to make iron iodide. You found it easy to get the iron and iodine back again. Very little heat energy was needed. In Unit C1, you also used iron - to chase the copper out of a solution of copper sulphate. Do you remember that experiment with the iron nail? The copper came out quite quickly and again very little energy was needed. Not all "breaking up" type reactions are so easy!



Iron and copper occur in Zimbabwe in quite large quantities and they are used as elements on their own in many different ways. Discuss with your teacher some uses of iron that you know about.

Copper is found in Zimbabwe as copper sulphide and iron is found as iron oxide. When compounds are found naturally in this way, they are often called ORES. First of all, the metals have to be got out, or EXTRACTED from their ores and then they have to be made very pure (PURIFIED)

Let us think about the iron first of all. Your teacher will give you a piece of iron ore which comes from Redcliff near Kwekwe. This is how the iron ore looks when it is taken from the earth's crust. The red coloured substance is iron oxide. The iron must be robbed of its oxygen by a substance which is more active than the iron. This more active substance will join up with the oxygen from the oxide taking the place of the iron and leaving it on its own. A reaction in which one substance takes the place of another is called a DISPLACEMENT reaction.

The active substance that we choose will need to be cheap and easily obtained because we shall use up quite a lot of it when extracting the iron.

The active substance that is chosen for use in iron extraction is carbon. It is very common and it is not expensive. The carbon used in industry is in the form called COKE.

As you know, carbon is not a metal. At room temperature it is not very reactive. However, at high temperatures it becomes much more reactive and is able to displace the iron from its ore.

In a large industrial extraction, the iron ore is placed in a BLAST FURNACE.

Study the diagrams on page 35 and 36, and read about the blast furnace on page 37, to understand how it works.

Picture of a blast furnace.

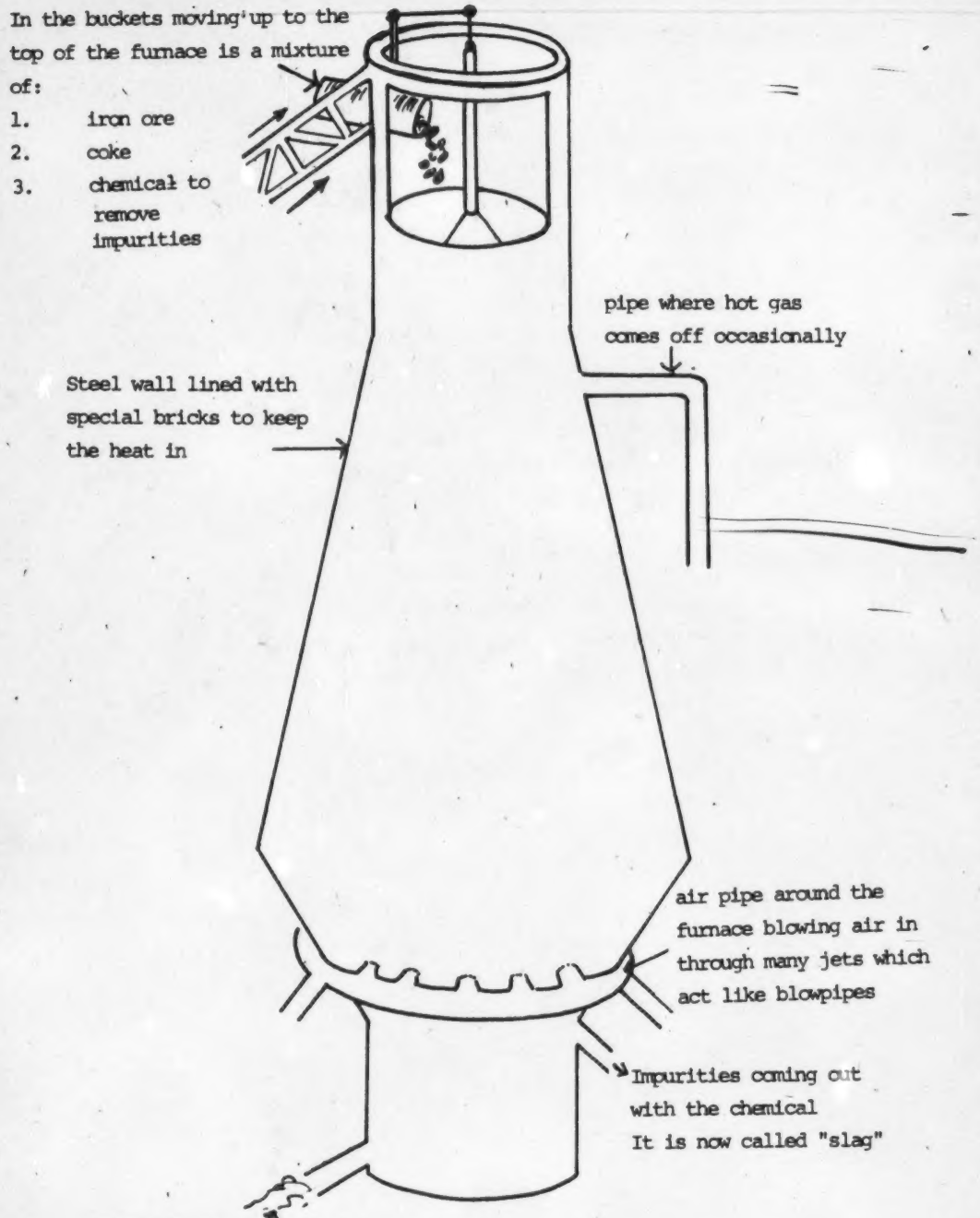
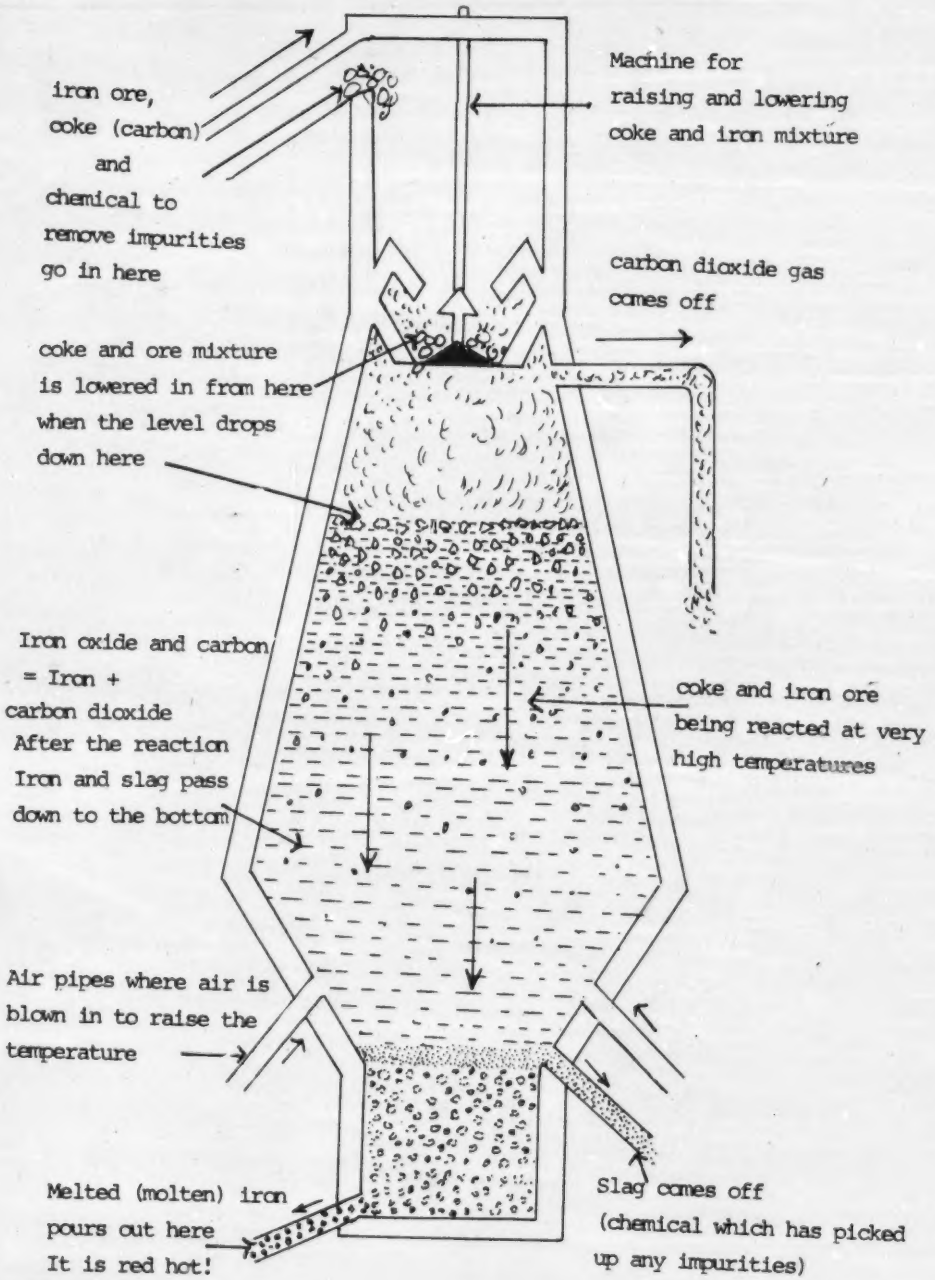

In the buckets moving up to the top of the furnace is a mixture of:
1. iron ore
2. coke
3. chemical to remove impurities
pipe where hot gas comes off occasionally
Steel wall lined with special bricks to keep the heat in
air pipe around the furnace blowing air in through many jets which act like blowpipes
Impurities coming out with the chemical
It is now called "slag"
Molten (melted) red-hot iron pouring out

Diagram to show what happens inside the blast furnace.



In the blast furnace, iron ore is mixed with carbon (coke) and hot air is blown into the furnace. The carbon reacts with the iron oxide to form carbon dioxide and iron. The iron is removed at the bottom of the furnace.

$$\text{carbon} + \text{iron oxide} \xrightarrow[\text{temperatures}]{\text{high}} \text{carbon dioxide} + \text{iron}$$

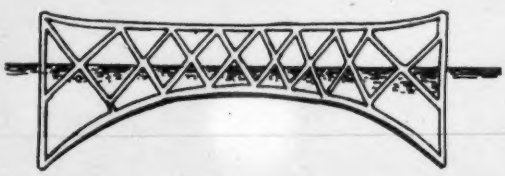
This is the chemical formula for the displacement reaction. Addition of other chemicals helps to remove impurities by reacting with them to form SLAG. The slag is removed from a separate hole at the bottom of the furnace. In this reaction carbon has displaced iron.

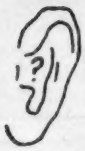
The iron which is removed from the blast furnace is not pure. It can be used in its impure state, when it is called PIG IRON, or CAST IRON, or it can be purified into WROUGHT IRON by further reactions.

a cast iron pot

a wrought iron gate

When heated with a small amount of carbon under special conditions, iron becomes STEEL. Steel is very hard, tough and strong. It is used to make many different articles such as nails, car bodies, railway lines, bridges, ships. pipes, tools etc.





You cannot construct a blast furnace in the classroom! However you can see the effect of a hot flame on a mixture of iron oxide and carbon. For this experiment you will need to use a BLOWPIPE. A blowpipe is a simple piece of apparatus which is used for changing the direction of a hot flame. Watch your teacher as he shows you how to use a blowpipe.
Now you can try it for yourself!

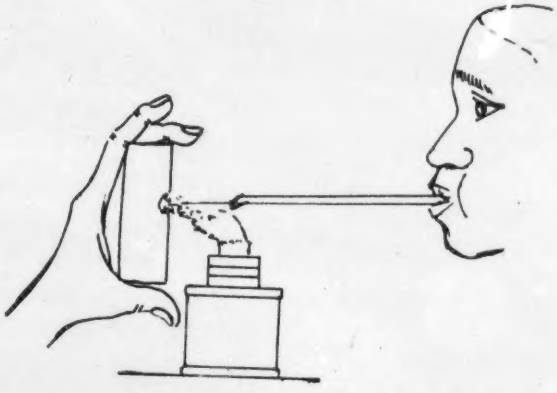
EXPERIMENT 17 : To extract iron from red iron oxide

You will need

1 spatula iron oxide
a piece of charcoal at least 2 cm x 4 cm
blowpipe
burner

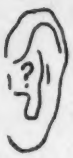
You will have to make a hollow in the piece of charcoal to hold the iron oxide. Use the end of your spatula to dig into the charcoal. You do not have to make a very large hole(about the size of your small finger nail)

Put the iron oxide into the hole you have made and blow the flame gently onto it. You might have to practice for some time before you get it right! (see diagram below)



If you are successful, you will see grey metallic iron in the hole.

When you have finished answer Exercise 12.



Now look at a piece of copper ore. The copper in this ore is in the form of copper sulphide. You can see it in the shiny gold parts of the ore.
Your teacher will tell you more about the copper ore.

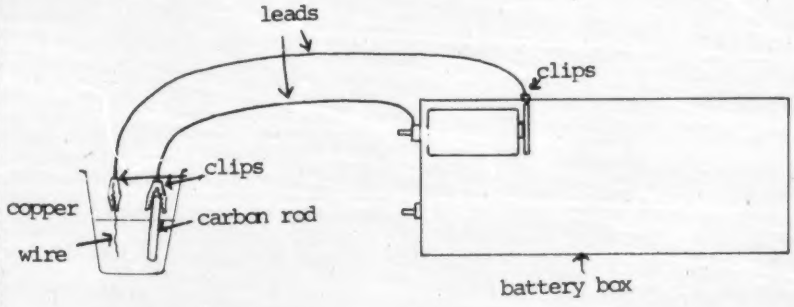
Copper is extracted from sulphide ores by first roasting it to form the oxide, and then by displacing the copper in a series of reactions. Once the copper is extracted, it must be purified. You will be able to get an idea of how this is done in the following experiment.

EXPERIMENT 18: To purify copper

You will need

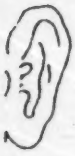
a sample of copper (you will use a piece of copper wire)
spatula stirrer
carbon rod
plastic cup half full of water
½ spatula copper sulphate
torch cell in a battery box
2 leads and crocodile clips

Put the copper sulphate in the cup of water and stir until it is dissolved.
Set up the apparatus as shown in the diagram.
Your teacher will help you to set up the battery box with one battery.

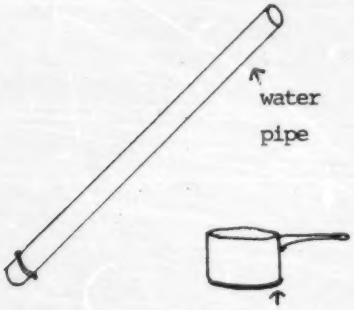


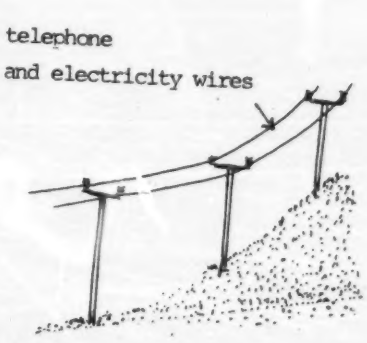
Observe what happens and then answer Exercise 13.

For copper purification in industry, this process is carried out in a copper REFINERY. The process is slightly different from the one you used in Experiment 18. In a refinery, the impure cooper is a big fat sheet. Your copper wire took the place of the impure copper. In place of a carbon rod there is a thin sheet of pure copper. (You used the carbon rod because it was easy to see the copper going onto it.)
When electricity is switched on, the copper comes off the impure sheet, travels through the solution, and goes onto the pure sheet. When the pure sheet is big and fat, it is taken away and the copper is used for useful articles. The impure sheet gets smaller and smaller. When most of the copper has left it, the impure sheet itself starts to break up and bits of impurity fall to the bottom of the tank. When all the copper is removed, the process is repeated.

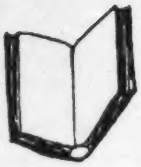


Copper is an important metal with many uses. Can you suggest some to your teacher? What metallic properties are being used in each of these useful articles?

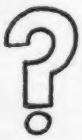




There are many other metals which are found in Zimbabwe. They have many different uses. Perhaps you could do a class project on some other metals. You could also try to get permission to visit a mine or a purification plant in your area. Our mineral wealth is an important part of our economy. Try to find out more about it!



This unit has introduced you to some basic chemical ideas. Before you read the summary, read and revise Part 3. Then go to "How much do you know? "



HOW MUCH DO YOU KNOW?

1. Write a brief description of what happens in the blast furnace.

2. How is copper refined in industry?

SUMMARY UNIT F2

1. The earth is made up of many different elements which are mostly in the form of compounds. The most abundant element is oxygen.

2. Oxygen occupies one fifth of the air. It may be detected by methylene blue indicator which turns blue when oxygen is present.

3. Burning, rusting and tarnishing are all reactions with oxygen. The product is an oxide.

4. Carbon dioxide is detected by bicarbonate indicator which goes from blue-red (purple) to yellow.

5. Universal Indicator Paper shows acidic and basic properties by changing colour over a pH range from 1 to 14. The neutral point has a pH of 7.
   Acids have a pH of between 1 and 7, bases have a pH of between 7 and 14.

6. An acid neutralises a base.

7. Carbonates give off carbon dioxide when they react with acids.

8. Metals have basic oxides. Non metals have acidic oxides.

9. Metals are hard and shiny. They can be bent.
   They allow heat to pass through them easily.

10. An activity series of the metals can be drawn up.

11. More reactive elements can displace less reactive elements.

12. All acids contain hydrogen.

13. When an acid reacts with the more reactive metals, hydrogen gas is displaced.

14. Hydrogen is a colourless gas which burns with a pop. The flame is pale blue.

15. Metals may be extracted from their ores by displacement. Carbon is useful for this.

16. Iron is extracted in a blast furnace.

17. Copper is extracted by displacement and refined (purified) using electrical energy.

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